LEVEL II SCOUR ANALYSIS FOR BRIDGE 37 (ANDOVT00110037) on STATE ROUTE 11, crossing the MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VERMONT

Open-File Report 98-416

Prepared in cooperation with
VERMONT AGENCY OF TRANSPORTATION
and
FEDERAL HIGHWAY ADMINISTRATION

U.S. Department of the Interior

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By ERICK M. BOEHMLER AND LORA K. STRIKER

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U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Slope	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Velocity and Flow	
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer [$(m^3/s)/km^2$

OTHER ABBREVIATIONS

BF	bank full	LWW	left wingwall
cfs	cubic feet per second	Max	maximum
D_{50}	median diameter of bed material	MC	main channel
DS	downstream	RAB	right abutment
elev.	elevation	RABUT	face of right abutment
f/p	flood plain	RB	right bank
ft^2	square feet	ROB	right overbank
ft/ft	feet per foot	RWW	right wingwall
FEMA	Federal Emergency Management Agency	TH	town highway
FHWA	Federal Highway Administration	UB	under bridge
JCT	junction	US	upstream
LAB	left abutment	USGS	United States Geological Survey
LABUT	face of left abutment	VTAOT	Vermont Agency of Transportation
LB	left bank	WSPRO	water-surface profile model
LOB	left overbank	yr	year

In this report, the words “right” and “left” refer to directions that would be reported by an observer facing downstream.

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929-- a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

In the appendices, the above abbreviations may be combined. For example, USLB would represent upstream left bank.

LEVEL II SCOUR ANALYSIS FOR BRIDGE 37 (ANDOVT00110037) ON STATE ROUTE 11, CROSSING THE MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VERMONT

By **Erick M. Boehmler and Lora K. Striker**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure ANDOVT00110037 on State Route 11 crossing the Middle Branch Williams River, Andover, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (FHWA, 1993). Results of a Level I scour investigation also are included in appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in appendix D.

The site is in the Green Mountain section of the New England physiographic province in south-central Vermont. The 5.35-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture on the right bank upstream and the left bank downstream, and forest on the left bank upstream and the right bank downstream.

In the study area, the Middle Branch Williams River has an incised, sinuous channel with a slope of approximately 0.023 ft/ft, an average channel top width of 47 ft and an average bank height of 10 ft. The channel bed material ranges from gravel to boulders with a median grain size (D_{50}) of 48.8 mm (0.160 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 29, 1996, indicated that the reach was stable.

The State Route 11 crossing of the Middle Branch Williams River is a 58-ft-long, two-lane bridge consisting of one 56-foot concrete Tee-beam span (Vermont Agency of Transportation, written communication, March 29, 1995). The opening length of the structure parallel to the bridge face is 49.8 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 75 degrees to the opening while the opening-skew-to-roadway is 60 degrees.

A scour hole 2.5 ft deeper than the mean thalweg depth was observed along the left abutment during the Level I assessment. Scour protection measures at the site included type-3 (less than 48 inches diameter) and type-4 (less than 60 inches diameter) stone fill. Type-3 stone fill was observed on the upstream right bank, the upstream end of the upstream right wingwall, the downstream end of the downstream left wingwall, and the downstream left bank. Type-4 stone fill was observed on the upstream left bank and the upstream end of the upstream left wingwall. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge was determined and analyzed as another potential worst-case scour scenario. Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 2.2 to 5.2 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 5.9 to 12.6 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and Davis, 1995, p. 46). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

Saxtons River, VT, 1957 and Ludlow, VT, 1929 Quadrangles
Contour Interval, 20 feet

NORTH

Figure 1. Location of study area on two USGS 1:62,500 scale maps.

Figure 2. Location of study area on Vermont Agency of Transportation town highway map.

LEVEL II SUMMARY

Structure Number ANDOVT00110037 ***Stream*** Middle Branch Williams River

County Windsor ***Road*** VT 11 ***District*** 2

Description of Bridge

Bridge length 58 ***ft*** ***Bridge width*** 32.2 ***ft*** ***Max span length*** 56 ***ft***

Alignment of bridge to road (on curve or straight) Straight

Abutment type Vertical, concrete ***Embankment type*** Sloping nearly vertical

Stone fill on abutment? No ***Date of inspection*** 8/29/96

Description of stone fill Type-3 was observed at the upstream end of the upstream right wingwall and the downstream end of the downstream left wingwall. Type-4 was observed at the upstream end of the upstream left wingwall.

Brief description of piers/abutments Abutments and wingwalls are concrete. There is a two foot deep scour hole in front of the upstream left wingwall which becomes as much as 2.5 feet deep along the left abutment.

Is bridge skewed to flood flow according to Yes ***survey?*** Yes ***Angle*** 75

There is a severe channel bend at the upstream face of the bridge. The scour hole has developed where the flow impacts the upstream left wingwall and the left abutment.

Debris accumulation on bridge at time of Level I or Level II site visit:

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	8/29/96	0	0
Level II	8/29/96	0	0

Potential for debris Moderate. Trees were observed on the banks where bank erosion also was evident upstream.

Describe any features near or at the bridge that may affect flow (include observation date) None were observed on 8/29/96.

Description of the Geomorphic Setting

General topography The channel is located in a moderate relief valley setting with little if any flood plain and steep valley walls on both sides.

Geomorphic conditions at bridge site: downstream (DS), upstream (US)

Date of inspection 8/29/96

DS left: Steep channel bank to the State Route 11 roadway

DS right: Steep channel bank and a narrow, irregular overbank.

US left: Steep channel bank and valley wall.

US right: Steep channel bank and a narrow overbank including the State Route 11 roadway.

Description of the Channel

Average top width 47 ft ***Average depth*** 10 ft

Predominant bed material Cobbles / Gravel ***Bank material*** Gravel/Cobbles

Perennial but flashy, and sinuous with semi- alluvial channel boundaries and irregular point and lateral bars.

8/29/96

Vegetative co Grass and brush.

DS left: Shrubs, brush, and small trees.

DS right: Trees.

US left: Pasture and small trees.

US right:

Do banks appear stable? Yes

date of observation.

None were observed on 8/29/96

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 5.35 ***mi***^{2}

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	***Percent of drainage area***
New England / Green Mountain	100

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***:

Is there a USGS gage on the stream of interest? No

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi***^{2}

Is there a lake/p No

Calculated Discharges

Q100 1,850 ***ft***^{3}***/s*** ***Q500*** 2,720 ***ft***^{3}***/s***

The 100- and 500-year discharges are based on a drainage area relationship [(5.35/5.65)exp 0.81] with flood frequency estimates determined for the hydraulic model at bridge number 38 in Andover (Striker, 1997). Bridge number 38 crosses the Middle Branch Williams River downstream of this site and has a 5.65 square mile drainage area. The discharge values adjusted for drainage area were within a range defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887). Each curve was extended graphically to the 500-year event.

Description of the Water-Surface Profile Model (WSPRO) Analysis

Datum for WSPRO analysis (USGS survey, sea level, VTAOT plans) USGS survey

Datum tie between USGS survey and VTAOT plans Subtract 21.5 feet from the USGS survey to obtain VTAOT plans' datum.

Description of reference marks used to determine USGS datum. RM6 is a chiseled "X" on top of the right abutment at the downstream end (elev. 479.90 ft, arbitrary survey datum). RM7 is a chiseled "X" on top of the downstream left wingwall at the downstream face of the bridge (elev. 479.72 ft, arbitrary survey datum). RM8 is a chiseled "X" on top of the right abutment at the upstream end (elev. 479.74 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-57	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	29	1	Road Grade section
APPRO	82	2	Modelled Approach section (Templated from APTEM)
APTEM	111	1	Approach section as surveyed (Used as a template)

[1] For location of cross-sections see plan-view sketch included with Level I field form, appendix E.
For more detail on how cross-sections were developed see WSPRO input file.

Data and Assumptions Used in WSPRO Model

Hydraulic analyses of the reach were done by use of the Federal Highway Administration's WSPRO step-backwater computer program (Shearman and others, 1986, and Shearman, 1990). The analyses reported herein reflect conditions existing at the site at the time of the study. Furthermore, in the development of the model it was necessary to assume no accumulation of debris or ice at the site. Results of the hydraulic model are presented in the Bridge Hydraulic Summary, appendix B, and figure 7.

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.055 to 0.065, and overbank "n" values ranged from 0.045 to 0.065.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0231 ft/ft, which was estimated from thalweg points surveyed downstream of the bridge.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.009 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 480.2 *ft*
Average low steel elevation 476.2 *ft*

100-year discharge 1,850 *ft^3/s*
Water-surface elevation in bridge opening 476.3 *ft*
Road overtopping? No *Discharge over road* -- *ft^3/s*
Area of flow in bridge opening 187 *ft^2*
Average velocity in bridge opening 9.8 *ft/s*
Maximum WSPRO tube velocity at bridge 12.1 *ft/s*

Water-surface elevation at Approach section with bridge 480.2
Water-surface elevation at Approach section without bridge 477.3
Amount of backwater caused by bridge 2.9 *ft*

500-year discharge 2,720 *ft^3/s*
Water-surface elevation in bridge opening 476.3 *ft*
Road overtopping? Yes *Discharge over road* 289 *ft^3/s*
Area of flow in bridge opening 187 *ft^2*
Average velocity in bridge opening 13.1 *ft/s*
Maximum WSPRO tube velocity at bridge 16.0 */s*

Water-surface elevation at Approach section with bridge 480.6
Water-surface elevation at Approach section without bridge 478.9
Amount of backwater caused by bridge 1.7 *ft*

Incipient overtopping discharge 1,890 *ft^3/s*
Water-surface elevation in bridge opening 476.3 *ft*
Area of flow in bridge opening 187 *ft^2*
Average velocity in bridge opening 9.9 *ft/s*
Maximum WSPRO tube velocity at bridge 12.3 *ft/s*

Water-surface elevation at Approach section with bridge 480.3
Water-surface elevation at Approach section without bridge 477.4
Amount of backwater caused by bridge 2.9 *ft*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analyses for the 100- and 500-year discharges are presented in tables 1 and 2 and the scour depths are shown graphically in figure 8.

At this site, each modeled discharge resulted in orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146). The computed streambed armoring depths suggest that armoring will not limit the depth of contraction scour.

For comparison, contraction scour was also computed by use of the Laursen clear-water (Richardson and Davis, 1995, p. 32, equation 20) contraction scour equation and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144). Furthermore, for the 100-year and incipient-overtopping discharges, which resulted in unsubmerged orifice flow, contraction scour was computed by substituting estimates for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to these substitutions also are provided in appendix F.

Abutment scour was computed by use of the Froehlich equation (Richardson and Davis, 1995, p. 48, equation 28). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

The length to depth ratio of the embankment blocking flow exceeded 25 for the left abutment at each modeled discharge. Although the HIRE equation (Richardson and Davis, 1995, p. 49, equation 29) generally is applicable when this ratio exceeds 25, the results from the HIRE equation were not used for this analysis. Hydraulic Engineering Circular 18 recommends that the field conditions be similar to those from which the HIRE equation was derived (Richardson and Davis, 1995). Since the equation was developed from Army Corps. of Engineers' data obtained for spur dikes in the Mississippi River, the HIRE equation results were assumed not to apply for the narrow, incised, upland valley at this site.

Scour Results

Contraction scour:	*100-year discharge*	*500-year discharge*	*Incipient overtopping discharge*
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	2.2	5.2	2.4
Depth to armoring	18.0	26.9	17.7
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	11.9	12.6	12.0
Right abutment	5.9	6.9	5.9
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-year discharge	*500-year discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	2.5	1.8	2.5
Right abutment	2.5	1.8	2.5
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

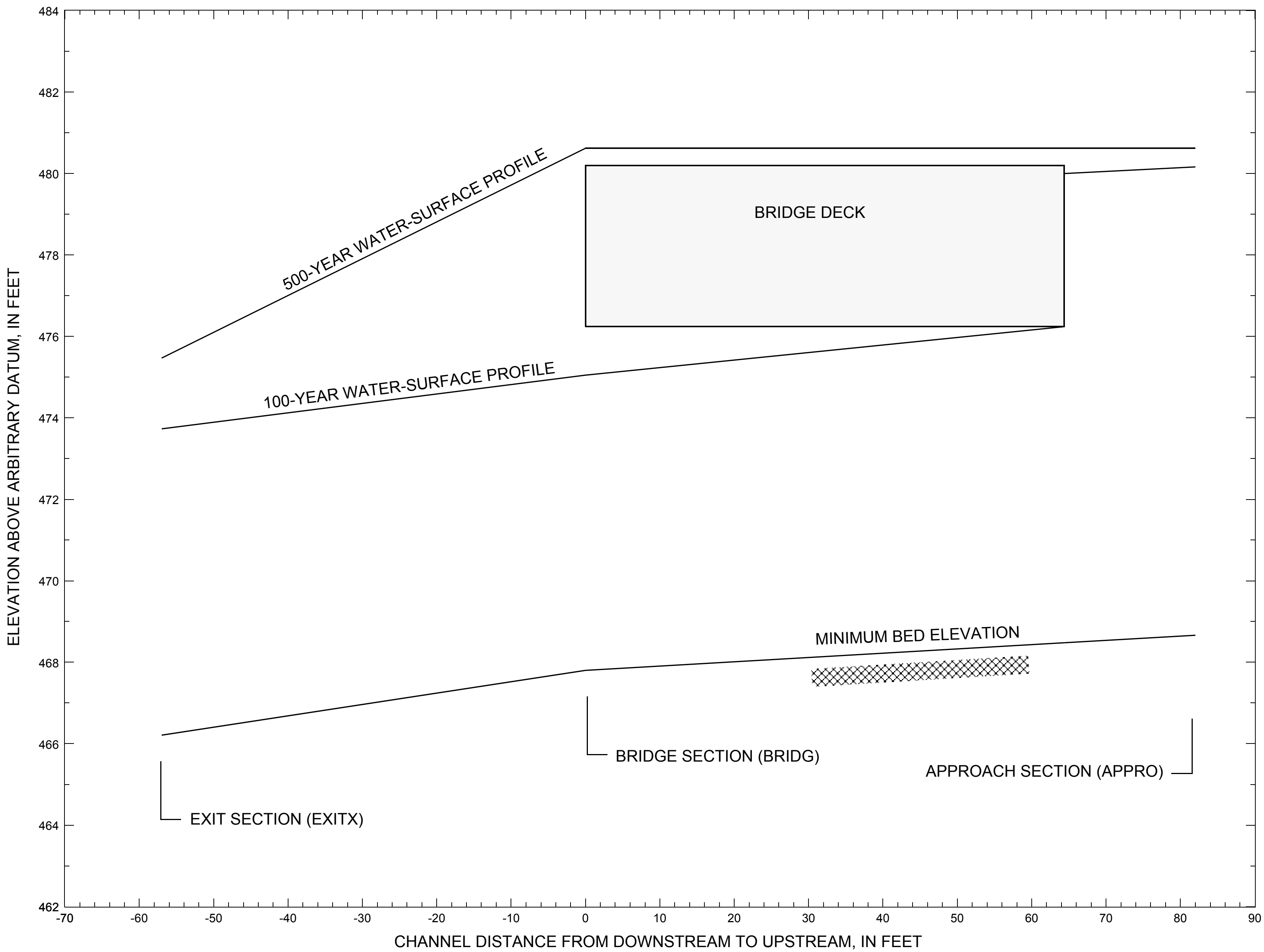

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure ANDOVT00110037 on State Route 11, crossing the Middle Branch Williams River, Andover, Vermont.

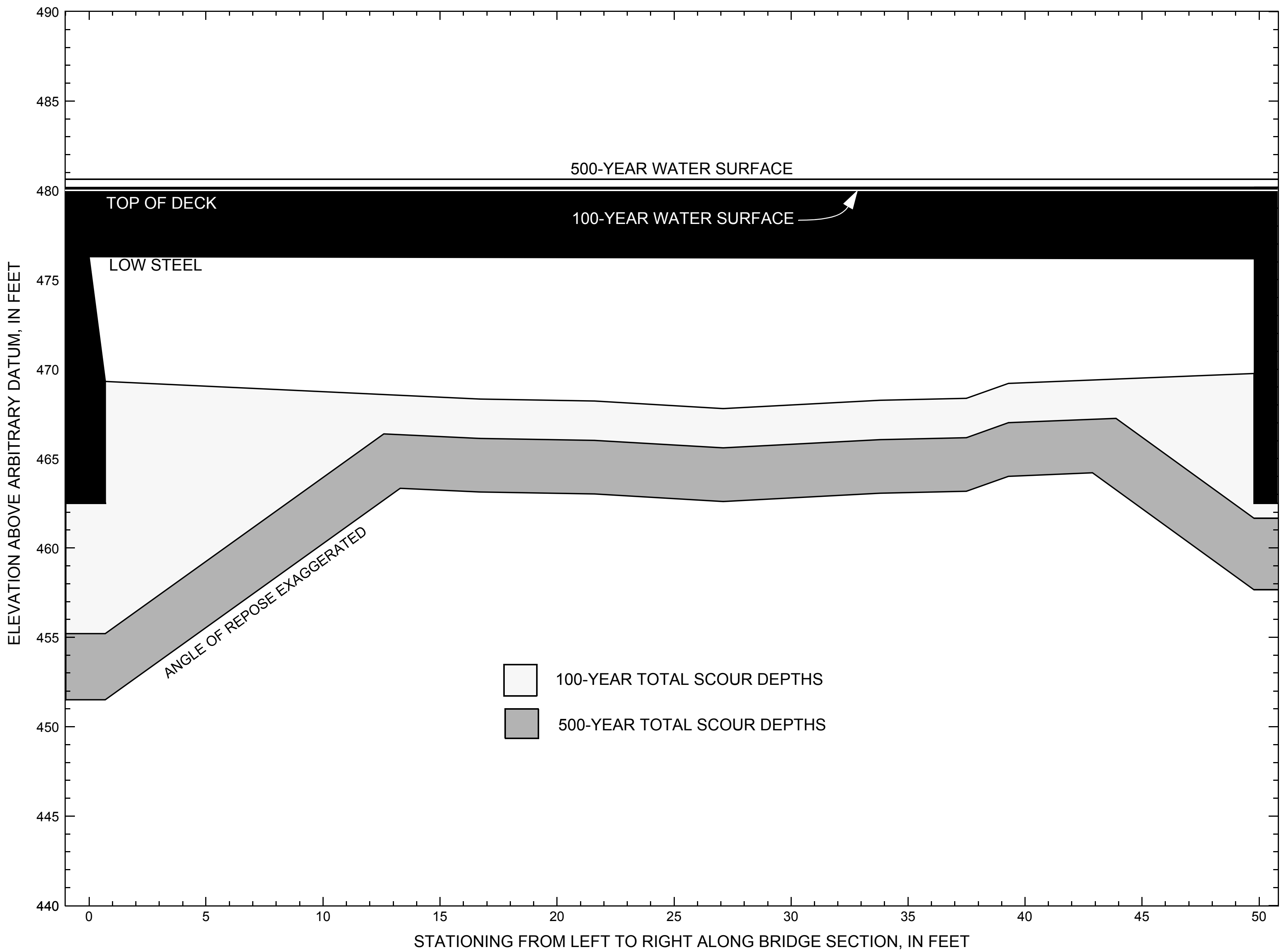

Figure 8. Scour elevations for the 100- and 500-year discharges at structure ANDOVT00110037 on State Route 11, crossing the Middle Branch Williams River, Andover, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure ANDOVT00110037 on State Route 11, crossing the Middle Branch Williams River, Andover, Vermont.

[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-year discharge is 1,850 cubic-feet per second											
Left abutment	0.0	454.4	476.3	462.5	469.3	2.2	11.9	--	14.1	455.2	-7.3
Right abutment	49.8	454.8	476.2	462.5	469.8	2.2	5.9	--	8.1	461.7	-0.8

1.Measured along the face of the most constricting side of the bridge.

2.Arbitrary datum for this study.

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure ANDOVT00110037 on State Route 11, crossing the Middle Branch Williams River, Andover, Vermont.

[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-year discharge is 2,720 cubic-feet per second											
Left abutment	0.0	454.4	476.3	462.5	469.3	5.2	12.6	--	17.8	451.5	-11.0
Right abutment	49.8	454.8	476.2	462.5	469.8	5.2	6.9	--	12.1	457.7	-4.8

1.Measured along the face of the most constricting side of the bridge.

2.Arbitrary datum for this study.

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U.S. Geological Survey, 1957, Saxtons River, Vermont 15 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Contour Interval, 20 feet, Scale 1:62,500.

U.S. Geological Survey, 1929, Ludlow, Vermont 15 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Contour Interval, 20 feet, Scale 1:62,500.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File ando037.wsp
T2        Hydraulic analysis for structure ANDOVT00111003   Date: 28-FEB-97
T3        VT 11 CROSSING MIDDLE BR WILLIAMS R, 2.4 MILES EAST OF JNCT. VT 121
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1850.0   2720.0   1890.0
SK          0.0231   0.0231   0.0231
*
XS   EXITX    -57
GR          -16.6, 479.38
GR           -7.1, 475.25      0.0, 469.83      7.1, 466.89     10.8, 466.21
GR           14.4, 466.23     18.9, 466.77     22.4, 467.11     24.9, 467.82
GR           30.9, 473.39     48.9, 476.80    146.9, 475.05    201.9, 476.36
GR          230.9, 477.72    254.9, 487.56
*          -193.0, 487.30   -176.0, 485.11   -136.0, 482.37   -104.0, 475.69
*           -44.0, 474.59
*
N             0.065       0.055
SA                   48.9
*
XS   FULLV      0  * * *   0.0300
*
*             SRD     LSEL    XSSKEW
BR   BRIDG      0    476.24      60.0
GR            0.0, 476.29      0.7, 469.31     16.7, 468.33     21.6, 468.22
GR           27.1, 467.80     30.0, 468.01     33.8, 468.26     37.5, 468.37
GR           39.3, 469.21     49.8 469.76      49.8, 476.18     0.0, 476.29
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      67.2 * *    49.5      9.0
N           0.055
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     29      32.2     1
GR         -236.8, 489.49   -215.0, 482.84   -145.0, 481.92   -125.0, 480.11
GR            0.0, 480.19    186.8, 482.00    482.1, 489.45
*
XT   APTEM    111
GR         -191.4, 488.82   -151.4, 485.85   -129.5, 480.26    -90.1, 479.95
GR          -38.5, 479.30      0.0, 478.48      4.8, 471.46     11.3, 469.57
GR           13.5, 469.19     16.1, 469.00     18.6, 469.13     21.4, 468.92
GR           24.0, 469.65     28.0, 470.72     31.7, 475.17     41.1, 479.87
GR           85.8, 481.12    119.8, 484.26    164.0, 489.05
*
AS   APPRO      82 * * * 0.009
GT
N           0.065        0.065        0.045
SA                   0.0          41.1
*
HP 1 BRIDG   476.29 1 476.29
HP 2 BRIDG   476.29 * * 1850
HP 1 BRIDG   475.05 1 475.05
HP 1 APPRO   480.16 1 480.16
HP 2 APPRO   480.16 * * 1850
*
HP 1 BRIDG   476.29 1 476.29
HP 2 BRIDG   476.29 * * 2449
HP 2 RDWAY   480.62 * *  289
HP 1 APPRO   480.62 1 480.62
HP 2 APPRO   480.62 * * 2720
*
HP 1 BRIDG   476.29 1 476.29
HP 2 BRIDG   476.29 * * 1890
HP 1 BRIDG   475.15 1 475.15
HP 1 APPRO   480.31 1 480.31
HP 2 APPRO   480.31 * * 1890
*
EX
ER
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APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File ando037.wsp
        Hydraulic analysis for structure ANDOVT00111003   Date: 28-FEB-97
        VT 11 CROSSING MIDDLE BR WILLIAMS R, 2.4 MILES EAST OF JNCT. VT 121
           *** RUN DATE & TIME: 05-18-98  14:00

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     187.   10416.     0.    63.                    ********
   476.29          187.   10416.     0.    63.  1.00     0.    50.********

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA         K        Q    VEL
       476.29     0.0    49.8   186.9   10416.    1850.  9.90

X STA.         0.0        6.4        8.6       10.8       12.9       14.9
  A(I)            21.7        8.2        8.0        7.9        7.9
  V(I)            4.26      11.29      11.52      11.69      11.67

X STA.        14.9       16.9       18.9       20.9       22.8       24.8
  A(I)             7.9        7.9        7.9        7.9        7.8
  V(I)           11.74      11.68      11.77      11.64      11.81

X STA.        24.8       26.6       28.5       30.3       32.3       34.3
  A(I)             7.8        7.7        7.8        7.9        7.9
  V(I)           11.79      12.07      11.93      11.73      11.77

X STA.        34.3       36.2       38.3       40.8       43.2       49.8
  A(I)             7.8        8.3        8.6        8.4       21.6
  V(I)           11.87      11.21      10.73      11.01       4.28

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     157.   11390.    25.    36.                        2249.
   475.05          157.   11390.    25.    36.  1.00     0.    50.   2249.

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      82.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     113.    2340.   130.   130.                         594.
             2     329.   27060.    41.    49.                        5292.
             3       5.      76.    20.    20.                          16.
   480.16          447.   29476.   191.   198.  1.43  -130.    61.   3244.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      82.

         WSEL     LEW     REW    AREA         K        Q    VEL
       480.16  -130.1    60.8   447.4   29476.    1850.  4.14

X STA.      -130.1      -14.7        5.2        6.9        8.3        9.8
  A(I)            86.3       56.2       15.2       14.6       14.4
  V(I)            1.07       1.65       6.09       6.32       6.43

X STA.         9.8       11.1       12.4       13.7       14.9       16.2
  A(I)            14.4       14.3       14.1       14.1       14.2
  V(I)            6.43       6.46       6.55       6.55       6.49

X STA.        16.2       17.4       18.6       19.8       21.0       22.2
  A(I)            13.8       13.7       13.4       13.7       13.3
  V(I)            6.72       6.76       6.91       6.75       6.95

X STA.        22.2       23.4       24.7       26.0       27.4       60.8
  A(I)            13.7       13.9       14.0       14.1       65.9
  V(I)            6.73       6.64       6.61       6.56       1.40
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WSPRO OUTPUT FILE (continued)

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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File ando037.wsp
        Hydraulic analysis for structure ANDOVT00111003   Date: 28-FEB-97
        VT 11 CROSSING MIDDLE BR WILLIAMS R, 2.4 MILES EAST OF JNCT. VT 121
           *** RUN DATE & TIME: 05-18-98  14:00

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     187.   10416.     0.    63.                     ********
   476.29          187.   10416.     0.    63.  1.00     0.    50.********

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       476.29     0.0    49.8   186.9   10416.    2449.  13.10

X STA.         0.0        6.4        8.6       10.8       12.9       14.9
  A(I)            21.7        8.2        8.0        7.9        7.9
  V(I)            5.64      14.95      15.24      15.47      15.45

X STA.        14.9       16.9       18.9       20.9       22.8       24.8
  A(I)             7.9        7.9        7.9        7.9        7.8
  V(I)           15.54      15.46      15.59      15.41      15.63

X STA.        24.8       26.6       28.5       30.3       32.3       34.3
  A(I)             7.8        7.7        7.8        7.9        7.9
  V(I)           15.61      15.98      15.79      15.53      15.58

X STA.        34.3       36.2       38.3       40.8       43.2       49.8
  A(I)             7.8        8.3        8.6        8.4       21.6
  V(I)           15.71      14.84      14.21      14.57       5.66

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      29.

         WSEL     LEW     REW    AREA        K        Q    VEL
       480.62  -130.6    44.4    69.7     865.     289.   4.14

X STA.      -130.6     -120.5     -114.5     -108.4     -102.1      -95.9
  A(I)             3.7        3.0        3.1        3.1        3.0
  V(I)            3.90       4.76       4.67       4.61       4.75

X STA.       -95.9      -89.5      -83.0      -76.3      -69.6      -63.6
  A(I)             3.2        3.1        3.2        3.2        2.9
  V(I)            4.58       4.60       4.50       4.54       5.03

X STA.       -63.6      -57.6      -50.9      -44.1      -37.0      -29.9
  A(I)             2.8        3.1        3.2        3.2        3.2
  V(I)            5.20       4.63       4.58       4.50       4.51

X STA.       -29.9      -22.7      -15.2       -7.8       -0.1       44.4
  A(I)             3.2        3.3        3.2        3.3        9.6
  V(I)            4.51       4.33       4.46       4.35       1.51

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      82.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     173.    4739.   132.   132.                        1122.
             2     348.   29697.    41.    49.                        5754.
             3      18.     384.    36.    36.                          74.
   480.62          539.   34820.   209.   217.  1.51  -132.    77.   3995.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      82.

         WSEL     LEW     REW    AREA        K        Q    VEL
       480.62  -131.9    77.3   539.4   34820.    2720.   5.04

X STA.      -131.9      -43.2      -13.8        4.9        6.7        8.3
  A(I)            88.8       52.8       60.3       17.4       17.0
  V(I)            1.53       2.58       2.25       7.81       8.00

X STA.         8.3        9.9       11.4       12.8       14.2       15.6
  A(I)            16.9       16.2       16.5       16.0       16.2
  V(I)            8.07       8.41       8.26       8.49       8.40

X STA.        15.6       16.9       18.2       19.6       20.9       22.1
  A(I)            15.9       15.8       15.4       15.5       15.3
  V(I)            8.54       8.58       8.81       8.78       8.89

X STA.        22.1       23.5       24.9       26.4       28.1       77.3
  A(I)            15.8       16.0       16.0       17.2       78.3
  V(I)            8.61       8.52       8.49       7.89       1.74
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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File ando037.wsp
        Hydraulic analysis for structure ANDOVT00111003   Date: 28-FEB-97
        VT 11 CROSSING MIDDLE BR WILLIAMS R, 2.4 MILES EAST OF JNCT. VT 121
           *** RUN DATE & TIME: 05-18-98  14:00

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     187.   10416.     0.    63.                    ********
   476.29          187.   10416.     0.    63.  1.00     0.    50.********

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA         K        Q    VEL
       476.29     0.0    49.8   186.9   10416.    1890.  10.11

X STA.         0.0         6.4         8.6        10.8        12.9        14.9
  A(I)            21.7         8.2         8.0         7.9         7.9
  V(I)            4.35       11.54       11.76       11.94       11.92

X STA.        14.9        16.9        18.9        20.9        22.8        24.8
  A(I)             7.9         7.9         7.9         7.9         7.8
  V(I)           12.00       11.93       12.03       11.89       12.06

X STA.        24.8        26.6        28.5        30.3        32.3        34.3
  A(I)             7.8         7.7         7.8         7.9         7.9
  V(I)           12.04       12.33       12.19       11.98       12.03

X STA.        34.3        36.2        38.3        40.8        43.2        49.8
  A(I)             7.8         8.3         8.6         8.4        21.6
  V(I)           12.12       11.45       10.97       11.24        4.37

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     160.   11648.    25.    36.                       2302.
   475.15          160.   11648.    25.    36.  1.00     0.    50.   2302.

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      82.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     132.    3048.   131.   131.                        753.
             2     336.   27909.    41.    49.                       5441.
             3       9.     145.    25.    25.                         30.
   480.31          476.   31101.   197.   204.  1.47  -131.    66.   3470.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      82.

         WSEL     LEW     REW    AREA         K        Q    VEL
       480.31  -130.7    66.2   476.4   31101.    1890.   3.97

X STA.      -130.7       -24.1         4.3         6.2         7.8         9.3
  A(I)            87.8        66.9        17.6        15.6        15.3
  V(I)            1.08        1.41        5.37        6.05        6.18

X STA.         9.3        10.7        12.1        13.4        14.7        16.0
  A(I)            14.9        14.9        14.7        14.8        14.9
  V(I)            6.33        6.34        6.41        6.39        6.34

X STA.        16.0        17.2        18.5        19.7        20.9        22.2
  A(I)            14.2        14.2        14.3        14.0        14.2
  V(I)            6.63        6.67        6.59        6.73        6.65

X STA.        22.2        23.4        24.7        26.2        27.6        66.2
  A(I)            14.4        14.1        15.1        14.7        69.6
  V(I)            6.57        6.69        6.28        6.41        1.36
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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File ando037.wsp
        Hydraulic analysis for structure ANDOVT00111003   Date: 28-FEB-97
        VT 11 CROSSING MIDDLE BR WILLIAMS R, 2.4 MILES EAST OF JNCT. VT 121
           *** RUN DATE & TIME: 05-18-98  14:00

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXITX:XS   ******    -5.     193.  1.44 *****  475.16  472.61   1850.  473.73
      -57. ******    33.   12163.  1.00 ***** *******    0.75    9.61

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.81     475.05     474.32

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   473.23     489.27    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   473.23     489.27     474.32

FULLV:FV      57.    -5.     179.  1.67  1.44  476.72  474.32   1850.  475.05
        0.    57.    31.   11174.  1.00  0.12    0.01    0.81   10.36
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      82.     1.     217.  1.13  1.70  478.41 *******   1850.  477.28
       82.    82.    36.   14801.  1.00  0.00    0.00    0.61    8.53
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =    474.30     479.00     479.24     476.24

 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

BRIDG:BR      57.     0.     187.  1.50 *****  477.79  474.25   1838.  476.29
        0. ******    50.   10416.  1.00 ***** *******    0.90    9.83

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.500  0.000  476.24 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      29.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

APPRO:AS      15.  -130.     448.  0.38  0.16  480.54  475.20   1850.  480.16
       82.    15.    61.   29492.  1.44  2.54   -0.01    0.57    4.13

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   479.97

                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q         K      AREA     VEL    WSEL
   EXITX:XS     -57.    -5.    33.   1850.   12163.      193.    9.61  473.73
   FULLV:FV       0.    -5.    31.   1850.   11174.      179.   10.36  475.05
   BRIDG:BR       0.     0.    50.   1838.   10416.      187.    9.83  476.29
   RDWAY:RG      29.**************      0.        0.        0.    1.00********
   APPRO:AS      82.  -130.    61.   1850.   29492.      448.    4.13  480.16

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS   ***********************

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    472.61    0.75  466.21  487.56************  1.44  475.16  473.73
   FULLV:FV    474.32    0.81  467.92  489.27  1.44  0.12  1.67  476.72  475.05
   BRIDG:BR    474.25    0.90  467.80  476.29************  1.50  477.79  476.29
   RDWAY:RG  ****************  480.11  489.49************  0.38  480.35********
   APPRO:AS    475.20    0.57  468.66  488.79  0.16  2.54  0.38  480.54  480.16
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WSPRO OUTPUT FILE (continued)

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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188              MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File ando037.wsp
        Hydraulic analysis for structure ANDOVT00111003   Date: 28-FEB-97
        VT 11 CROSSING MIDDLE BR WILLIAMS R, 2.4 MILES EAST OF JNCT. VT 121
           *** RUN DATE & TIME: 05-18-98  14:00

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXITX:XS   ******    -8.     277.  1.58 *****  477.04  474.20   2720.  475.47
      -57. ******   164.   17888.  1.05 ***** *******    1.01    9.82

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80     0.84     476.77     475.91

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   474.97     489.27    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   474.97     489.27     475.91

FULLV:FV      57.    -7.     249.  1.86  1.45  478.63  475.91   2720.  476.77
        0.    57.   147.   16311.  1.00  0.14    0.00    0.84   10.93
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80     0.85     478.95     476.79

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   476.27     488.79    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   476.27     488.79     476.79

APPRO:AS      82.   -34.     292.  1.44  1.75  480.38  476.79   2720.  478.94
       82.    82.    40.   21200.  1.07  0.00    0.00    0.85    9.31
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =    476.77     476.24

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

BRIDG:BR      57.     0.     187.  2.67 *****  478.96  475.43   2449.  476.29
        0. ******    50.   10416.  1.00 ***** *******    1.19   13.10

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  476.24 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF    VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      29.    50.  0.30  0.60  480.92    0.01     289.  480.62

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   289.   150.  -125.    25.   0.5   0.4   3.9   4.3   0.7   3.0
   RT:     0.    83.    25.   108.   0.8   0.4   3.6   3.7   0.6   3.0

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

APPRO:AS      15.  -132.     540.  0.60  0.28  481.22  476.79   2720.  480.62
       82.    15.    77.   34829.  1.51  2.54    0.01    0.68    5.04

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ****** ********

                  <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW     REW       Q         K      AREA      VEL    WSEL
   EXITX:XS      -57.     -8.    164.   2720.   17888.      277.     9.82  475.47
   FULLV:FV        0.     -7.    147.   2720.   16311.      249.    10.93  476.77
   BRIDG:BR        0.      0.     50.   2449.   10416.      187.    13.10  476.29
   RDWAY:RG       29.*******    289.    289.*********        0.     1.00  480.62
   APPRO:AS       82.   -132.     77.   2720.   34829.      540.     5.04  480.62

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS   ***********************


 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN     YMAX    HF     HO   VHD      EGL    WSEL
   EXITX:XS     474.20    1.01  466.21  487.56************  1.58  477.04  475.47
   FULLV:FV     475.91    0.84  467.92  489.27  1.45  0.14  1.86  478.63  476.77
   BRIDG:BR     475.43    1.19  467.80  476.29************  2.67  478.96  476.29
   RDWAY:RG   ****************  480.11  489.49  0.30******  0.60  480.92  480.62
   APPRO:AS     476.79    0.68  468.66  488.79  0.28  2.54  0.60  481.22  480.62
```
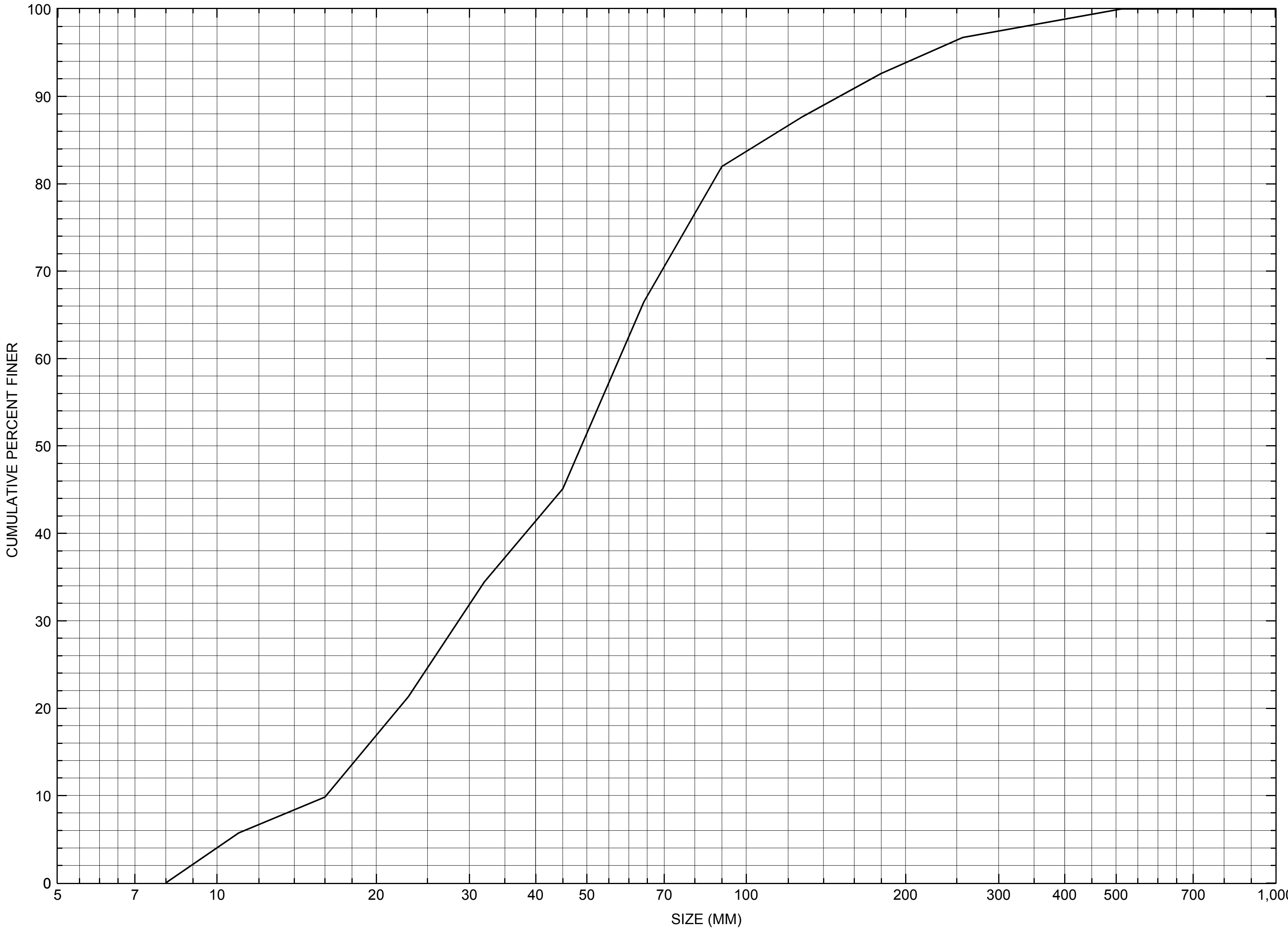

```
WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188              MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File ando037.wsp
        Hydraulic analysis for structure ANDOVT00111003   Date: 28-FEB-97
        VT 11 CROSSING MIDDLE BR WILLIAMS R, 2.4 MILES EAST OF JNCT. VT 121
           *** RUN DATE & TIME: 05-18-98  14:00

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXITX:XS   ******    -5.     196.  1.44 *****  475.27  472.67   1890.  473.83
      -57. ******    33.   12426.  1.00 ***** *******    0.75    9.63

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.81     475.15     474.40

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   473.33     489.27    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   473.33     489.27     474.40

FULLV:FV      57.    -5.     182.  1.68  1.43  476.83  474.40   1890.  475.15
        0.    57.    31.   11434.  1.00  0.12    0.01    0.81   10.39
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      82.     1.     220.  1.15  1.70  478.52 *******   1890.  477.37
       82.    82.    37.   15091.  1.00  0.00    0.00    0.61    8.59
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =    474.38     479.14     479.37     476.24

 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

BRIDG:BR      57.     0.     187.  1.54 *****  477.83  474.29   1857.  476.29
        0. ******    50.   10416.  1.00 ***** *******    0.90    9.94

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.500  0.000  476.24 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      29.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

APPRO:AS      15.  -131.     476.  0.36  0.16  480.67  475.26   1890.  480.31
       82.    15.    66.   31085.  1.47  2.55   -0.02    0.55    3.97

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   480.12

                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXITX:XS     -57.    -5.    33.   1890.   12426.     196.    9.63  473.83
   FULLV:FV       0.    -5.    31.   1890.   11434.     182.   10.39  475.15
   BRIDG:BR       0.     0.    50.   1857.   10416.     187.    9.94  476.29
   RDWAY:RG      29.**************      0.       0.       0.    1.00********
   APPRO:AS      82.  -131.    66.   1890.   31085.     476.    3.97  480.31

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS  ***********************

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    472.67    0.75  466.21  487.56************  1.44  475.27  473.83
   FULLV:FV    474.40    0.81  467.92  489.27  1.43  0.12  1.68  476.83  475.15
   BRIDG:BR    474.29    0.90  467.80  476.29************  1.54  477.83  476.29
   RDWAY:RG  ****************  480.11  489.49************  0.36  480.48********
   APPRO:AS    475.26    0.55  468.66  488.79  0.16  2.55  0.36  480.67  480.31
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure ANDOVT00110037, in Andover, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number ANDOVT00110037

General Location Descriptive

Data collected by *(First Initial, Full last name)* M. IVANOFF

Date *(MM/DD/YY)* 03 / 29 / 95

Highway District Number *(I - 2; nn)* 02

County *(FIPS county code; I - 3; nnn)* 027

Town *(FIPS place code; I - 4; nnnnn)* 01300

Mile marker *(I - 11; nnn.nnn)* 001130

Waterway *(I - 6)* MIDDLE BRANCH WILLIAMS R.

Road Name *(I - 7):* -

Route Number VT 11

Vicinity *(I - 9)* 2.4 MI E JCT VT 121

Topographic Map Saxtons.River

Hydrologic Unit Code: 01080107

Latitude *(I - 16; nnnn.n)* 43149

Longitude *(i - 17; nnnnn.n)* 72424

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20001600371401

Maintenance responsibility *(I - 21; nn)* 01

Maximum span length *(I - 48; nnnn)* 0056

Year built *(I - 27; YYYY)* 1929

Structure length *(I - 49; nnnnnn)* 000058

Average daily traffic, ADT *(I - 29; nnnnnn)* 002736

Deck Width *(I - 52; nn.n)* 322

Year of ADT *(I - 30; YY)* 92

Channel & Protection *(I - 61; n)* 6

Opening skew to Roadway *(I - 34; nn)* 60

Waterway adequacy *(I - 71; n)* 4

Operational status *(I - 41; X)* A

Underwater Inspection Frequency *(I - 92B; XYY)* N

Structure type *(I - 43; nnn)* 104

Year Reconstructed *(I - 106)* 1970

Approach span structure type *(I - 44; nnn)* 000

Clear span (*nnn.n ft*) _______

Number of spans *(I - 45; nnn)* 001

Vertical clearance from streambed (*nnn.n ft*) 8.0

Number of approach spans *(I - 46; nnnn)* 0000

Waterway of full opening (*nnn.n ft*^{2}) _______

Comments:

The structural inspection report of 11/10/93 indicates the structure is a concrete T-beam type bridge with an asphalt road surface. The left abutment has vertical hairline cracks below the bridge seat areas. There is a "popoff" at the top of the upstream right wingwall. The footings are not in view. The waterway has a poor alignment into the structure, and much of the flow is directed into the upstream end of left abutment. There is localized scour in this location, exposing some fairly large stones in the streambed, but again, the footing is not in view. The streambed consists of stone and gravel with a few moderate sized boulders.

Bridge Hydrologic Data

Is there hydrologic data available? N *if No, type ctrl-n h* VTAOT Drainage area *(mi^2)*: -

Terrain character: -

Stream character & type: -

Streambed material: -

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} - Q_{25} -

Q_{50} - Q_{100} - Q_{500} -

Record flood date *(MM / DD / YY)*: - / / Water surface elevation *(ft)*: -

Estimated Discharge *(cfs)*: - Velocity at Q - *(ft/s)*: -

Ice conditions *(Heavy, Moderate, Light)* : - Debris *(Heavy, Moderate, Light)*: -

The stage increases to maximum highwater elevation (*Rapidly, Not rapidly*): -

The stream response is (*Flashy, Not flashy*): -

Describe any significant site conditions upstream or downstream that may influence the stream's stage: -

Watershed storage area (*in percent*): -%

The watershed storage area is: - (*1-mainly at the headwaters; 2- uniformly distributed; 3-immediatly upstream oi the site*)

Water Surface Elevation Estimates for Existing Structure:

Peak discharge frequency	$Q_{2.33}$	Q_{10}	Q_{25}	Q_{50}	Q_{100}
Water surface elevation (*ft*)	-	-	-	-	-
Velocity (*ft / sec*)	-	-	-	-	-

Long term stream bed changes: -

Is the roadway overtopped below the Q_{100}? (*Yes, No, Unknown*): U Frequency: -

Relief Elevation (*ft*): - Discharge over roadway at Q_{100} (*ft^3/ sec*): -

Are there other structures nearby? (*Yes, No, Unknown*): U *If No or Unknown, type ctrl-n os*

Upstream distance (*miles*): - Town: - Year Built: -

Highway No. : - Structure No. : - Structure Type: -

Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (*ft^2*): -

Downstream distance (*miles*): - Town: - Year Built: -
Highway No. : - Structure No. : - Structure Type: -
Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (ft^2): -

Comments:
-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 5.35 mi^2 Lake/pond/swamp area 0 mi^2
Watershed storage *(ST)* 0 %
Bridge site elevation 1253 ft Headwater elevation 2894 ft
Main channel length 4.47 mi
10% channel length elevation 1266 ft 85% channel length elevation 1969 ft
Main channel slope *(S)* 209.67 ft / mi

Watershed Precipitation Data

Average site precipitation - in Average headwater precipitation - in
Maximum 2yr-24hr precipitation event *(I24,2)* - in
Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

Are plans available? Y *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: 4 / 1970

Project Number **BMA 6736** Minimum channel bed elevation: -

Low superstructure elevation: USLAB **454.69** DSLAB **454.41** USRAB **455.02** DSRAB **454.75**

Benchmark location description:

BM#1, (mark on) boulder about 272 feet right bankward on the roadway from the right abutment and 33 feet from the centerline of the roadway perpendicular in a downstream direction near the bottom of a grass slope on roadway embankment, elevation 500.00.

Reference Point (*MSL, Arbitrary, Other*): - Datum (*NAD27, NAD83, Other*): -

Foundation Type: **1** (*1-Spreadfooting; 2-Pile; 3- Gravity; 4-Unknown*)

If 1: Footing Thickness **2.0** Footing bottom elevation: **441.0**

If 2: Pile Type: - (*1-Wood; 2-Steel or metal; 3-Concrete*) Approximate pile driven length: -

If 3: Footing bottom elevation: -

Is boring information available? **N** *If no, type ctrl-n bi* Number of borings taken: -

Foundation Material Type: **3** (*1-regolith, 2-bedrock, 3-unknown*)

Briefly describe material at foundation bottom elevation or around piles:

NO FOUNDATION MATERIAL INFORMATION

Comments:

-

Cross-sectional Data

Is cross-sectional data available? N *If no, type ctrl-n xs*

Source (*FEMA, VTAOT, Other*)? -

Comments: **NO CROSS SECTION INFORMATION**

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

Source (*FEMA, VTAOT, Other*)? -

Comments: **NO CROSS SECTION INFORMATION**

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E:

LEVEL I DATA FORM

U. S. Geological Survey
Bridge Field Data Collection and Processing Form

Qa/Qc Check by: EW Date: 9/24/96
Computerized by: EW Date: 9/26/96
Reviewd by: EMB Date: 5/15/98

Structure Number ANDOVT00110037

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* R. HAMMOND Date *(MM/DD/YY)* 08 / 29 / 1996
2. Highway District Number 02 Mile marker 001130
County WINDSOR (027) Town ANDOVER (01300)
Waterway *(I - 6)* Middle Branch Williams River Road Name -
Route Number VT 11 Hydrologic Unit Code: 01080107
3. Descriptive comments:
The bridge is located 2.4 miles east of the junction with State Route 121, and 1 mile north of the Windsor/ Windham County line.

B. Bridge Deck Observations

4. Surface cover... LBUS 6 RBUS 4 LBDS 4 RBDS 6 Overall 6
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*
5. Ambient water surface... US 2 UB 1 DS 2 *(**1**- pool; **2**- riffle)*
6. Bridge structure type 1 *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*
7. Bridge length 58 *(feet)* Span length 56 *(feet)* Bridge width 32.2 *(feet)*

Road approach to bridge:

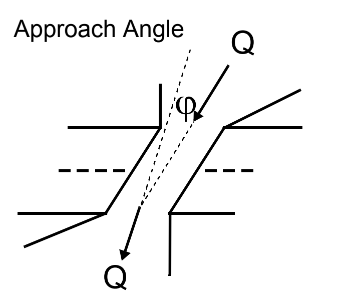
8. LB 1 RB 2 *(**0** even, **1**- lower, **2**- higher)*
9. LB 1 RB 1 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

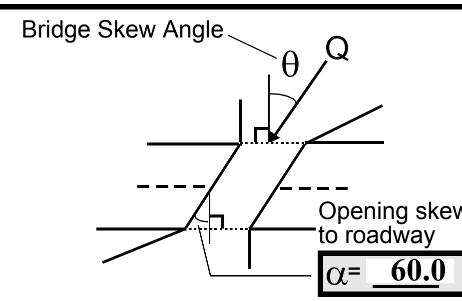
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	2	1
RBDS	0	-	2	0
LBDS	0	-	2	1

*Bank protection types: **0**- none; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*
*Erosion Severity: **0** - none; **1**- slight; **2**- moderate; **3**- severe*

Channel approach to bridge (BF):

15. Angle of approach: 20 16. Bridge skew: 75



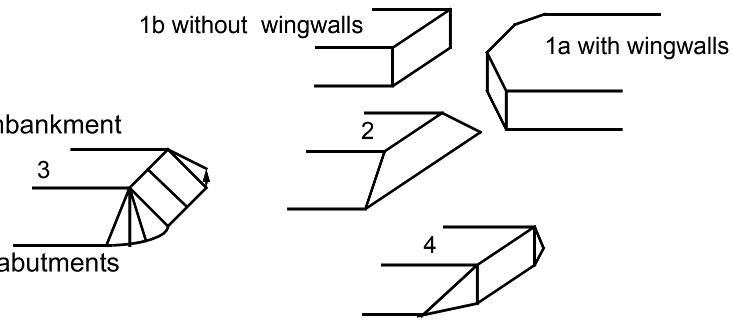


17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 3
Range? 6 feet UB *(US, UB, DS)* to 0 feet DS
Channel impact zone 2: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 67 feet DS *(US, UB, DS)* to 125 feet DS

*Impact Severity: **0**- none to very slight; **1**- Slight; **2**- Moderate; **3**- Severe*

18. Bridge Type: **1a**

1a- Vertical abutments with wingwalls
1b- Vertical abutments without wingwalls
2- Vertical abutments and wingwalls, sloping embankment
Wingwalls parallel to abut. face
3- Spill through abutments
4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.



19. Bridge Deck Comments (surface cover variations, measured bridge and span lengths, bridge type variations, approach overflow width, etc.)

#4: RBUS is VT11 and then pasture. LBDS is grass and brush and then VT11.
#7: The bridge has been widened. All measurements were taken from the bridge deck, though wingwalls extend under bridge. The upstream bridge length is 60.5 feet, the span length is 57.2 feet, and bridge width between the inside of the bridge rails is 29.2 feet. The downstream bridge length is 65.5 feet, the span length is 57.5 feet, and the bridge width from the outside edges of the bridge deck is 32.2 feet.

*** The USLWW extends 4.5 feet from upstream bridge deck edge to upstream end of LABUT. From the downstream end of the LABUT, the wingwall extends 14 feet to where the downstream bridge face ends.**

C. Upstream Channel Assessment

20. SRD	21. Bank height (BF) LB	21. Bank height (BF) RB	22. Bank angle (BF) LB	22. Bank angle (BF) RB	26. % Veg. cover (BF) LB	26. % Veg. cover (BF) RB	27. Bank material (BF) LB	27. Bank material (BF) RB	28. Bank erosion (BF) LB	28. Bank erosion (BF) RB
51.0	7.0			9.0	3	1	345	345	2	2

23. Bank width **55.0** 24. Channel width **35.0** 25. Thalweg depth **41.5** 29. Bed Material **435**

30 .Bank protection type: LB **4** RB **3** 31. Bank protection condition: LB **1** RB **1**

SRD - Section ref. dist. to US face *% Vegetation (Veg) cover: **1**- 0 to 25%; **2**- 26 to 50%; **3**- 51 to 75%; **4**- 76 to 100%*
*Bed and bank Material: **0**- organics; **1**- silt / clay, < 1/16mm; **2**- sand, 1/16 - 2mm; **3**- gravel, 2 - 64mm; **4**- cobble, 64 - 256mm; **5**- boulder, > 256mm; **6**- bedrock; **7**- manmade*
*Bank Erosion: **0**- not evident; **1**- light fluvial; **2**- moderate fluvial; **3**- heavy fluvial / mass wasting*
*Bank protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

32. Comments (bank material variation, minor inflows, protection extent, etc.):
#30: Right bank protection extends from approximately 200 feet upstream to 50 feet upstream (near the end of the USRWW). Left bank / wingwall protection extends from 5 feet under bridge to 20 feet under bridge.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **13 UB** 35. Mid-bar width: **23**

36. Point bar extent: **50** feet **US** (US, UB) to **15** feet **DS** (US, UB, DS) positioned **20** %LB to **100** %RB

37. Material: **4325**

38. Point or side bar comments (Circle Point or Side; Note additional bars, material variation, status, etc.):

#37: This point bar is mostly gravel and cobble with sand between larger material, and scattered boulders. Also, a point bar was observed on the left bank from 133 feet upstream to 205 feet upstream. The mid-bar distance is 195 feet and the mid-bar width is 7 feet. The bar is comprised of cobble, gravel and boulder.

39. Is a cut-bank present? **Y** (Y or if N type ctrl-n cb) 40. Where? **LB** (LB or RB)

41. Mid-bank distance: **85** 42. Cut bank extent: **70** feet **US** (US, UB) to **133** feet **US** (US, UB, DS)

43. Bank damage: **1** (**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)

44. Cut bank comments (eg. additional cut banks, protection condition, etc.):

Tree roots and the base of a tree are exposed. The material under the tree has fallen into the stream channel. However, the top of the bank remains. An additional cut-bank exists on the right bank from greater than 200 feet upstream to 130 feet upstream. The mid-bank is 164 feet and has type 1 bank damage.

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **30 UB**

47. Scour dimensions: Length **37** Width **8** Depth : **2.5** Position **0** %LB to **40** %RB

48. Scour comments (eg. additional scour areas, local scouring process, etc.):

This scour hole extends from 16 feet under bridge to 53 feet under bridge. The average thalweg depth ranges from 0.2 - 0.4 feet.

49. Are there major confluences? **N** (Y or if N type ctrl-n mc) 50. How many? **-**

51. Confluence 1: Distance **-** 52. Enters on **-** (LB or RB) 53. Type **-** (**1**- perennial; **2**- ephemeral)

Confluence 2: Distance **-** Enters on **-** (LB or RB) Type **-** (**1**- perennial; **2**- ephemeral)

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

55. Channel restraint (BF)? LB **2** RB _____ (**1**- natural bank; **2**- abutment; **3**- artificial levee)

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
23.5		0.5		2	7	7	-

58. Bank width (BF) **-** 59. Channel width **-** 60. Thalweg depth **90.0** 63. Bed Material **-**

*Bed and bank Material: **0**- organics; **1**- silt / clay, < 1/16mm; **2**- sand, 1/16 - 2mm; **3**- gravel, 2 - 64mm; **4**- cobble, 64 - 256mm; **5**- boulder, > 256mm; **6**- bedrock; **7**- manmade*

*Bank Erosion: **0**- not evident; **1**- light fluvial; **2**- moderate fluvial; **3**- heavy fluvial / mass wasting*

64. Comments (bank material variation, minor inflows, protection extent, etc.):

4325

-

65. Debris and Ice Is there debris accumulation? ____ (Y or N) 66. Where? Y____ (1- Upstream; 2- At bridge; 3- Both)

67. Debris Potential 1____ (1- Low; 2- Moderate; 3- High) 68. Capture Efficiency 2____ (1- Low; 2- Moderate; 3- High)

69. Is there evidence of ice build-up? 2___ (Y or N) Ice Blockage Potential N____ (1- Low; 2- Moderate; 3- High)

70. Debris and Ice Comments:

2

#68: Due to the angle of approach, debris and ice potential are moderate.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		10	90	2	1	2.5	-	90.0
RABUT	1	0	90			2	0	24.5

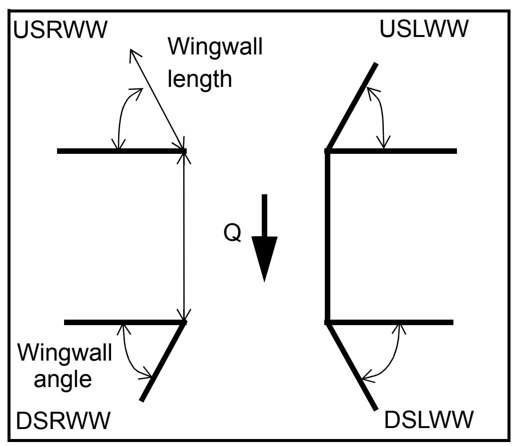
Pushed: LB or RB *Toe Location (Loc.): 0- even, 1- set back, 2- protrudes*
Scour cond.: 0- not evident; 1- evident (comment); 2- footing exposed; 3-undermined footing; 4- piling exposed; 5- settled; 6- failed
Materials: 1- Concrete; 2- Stone masonry or drywall; 3- steel or metal; 4- wood

79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

-
-
1
-

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						24.5	
USRWW:	Y		1		1	0.5	
DSLWW:	2.0		-		Y	46.5	
DSRWW:	1		0		-	68.0	



Wingwall materials: 1- Concrete; 2- Stone masonry or drywall; 3- steel or metal; 4- wood

82. Bank / Bridge Protection:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	-	0	Y	-	1	1	-	-
Condition	Y	-	1	-	2	2	-	-
Extent	1	-	0	4	3	0	0	-

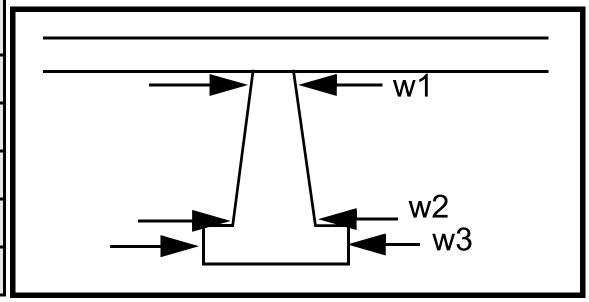
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
3
1
3
0
-
-

Piers:

84. Are there piers? _-_ *(Y or if N type ctrl-n pr)*

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1			**0.0**	**95.0**	**19.5**	**16.0**
Pier 2				**20.0**	**32.0**	**145.0**
Pier 3		-	-	**11.0**	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)		-	-	-	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type		-	-	-	***1**- Solid pier, **2**- column, **3**- bent*
88. Material		-	-	-	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape		-	-	-	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?		-	-	-	*Y- yes; N- no*
91. Attack ∠ (BF)		-	-	-	
92. Pushed		-	-	-	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles		-	-	-	
95. Cross-members		-	-	-	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition		-	-	-	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**N**	-	-	-	
98. Exposure depth	-	-	-	-	

99. Pier comments (eg. undermined penetration, protection and protection extent, unusual scour processes, etc.):

-
-
-
-
-
-
-
-
-
-

E. Downstream Channel Assessment

100.

SRD	Bank height (BF) LB	Bank height (BF) RB	Bank angle (BF) LB	Bank angle (BF) RB	% Veg. cover (BF) LB	% Veg. cover (BF) RB	Bank material (BF) LB	Bank material (BF) RB	Bank erosion (BF) LB	Bank erosion (BF) RB
-	-			-	-	NO	PIE	RS		

Bank width (BF) - Channel width - Thalweg depth - Bed Material _____

Bank protection type (Qmax): LB _____ RB _____ Bank protection condition: LB _____ RB _____

SRD - Section ref. dist. to US face *% Vegetation (Veg) cover: **1**- 0 to 25%; **2**- 26 to 50%; **3**- 51 to 75%; **4**- 76 to 100%*
*Bed and bank Material: **0**- organics; **1**- silt / clay, < 1/16mm; **2**- sand, 1/16 - 2mm; **3**- gravel, 2 - 64mm; **4**- cobble, 64 - 256mm; **5**- boulder, > 256mm; **6**- bedrock; **7**- manmade*
*Bank Erosion: **0**- not evident; **1**- light fluvial; **2**- moderate fluvial; **3**- heavy fluvial / mass wasting*
*Bank protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

Comments (eg. bank material variation, minor inflows, protection extent, etc.):

1
3
435
435
0
1
435
3
0
1
-
Right bank material appears to be protection for fields, which have reverted to woods. Some concrete is mixed in the bank material. Left bank material is mainly road embankment protection for State Route 11.

101. Is a drop structure present? ____ *(Y or N, if N type ctrl-n ds)* 102. Distance: - feet

103. Drop: - feet 104. Structure material: Lef *(**1**- steel sheet pile; **2**- wood pile; **3**- concrete; **4**- other)*

105. Drop structure comments (eg. downstream scour depth):
t bank protection extends from 15 feet downstream to more than 200 feet along State Route 11 road embankment.

106. Point/Side bar present? _____ *(Y or N. if N type ctrl-n pb)* Mid-bar distance: ______ Mid-bar width: ______

Point bar extent: ______ feet ____ *(US, UB, DS)* to ______ feet **N** *(US, UB, DS)* positioned **-** %LB to **NO** %RB

Material: **DR**

Point or side bar comments (Circle Point or Side; note additional bars, material variation, status, etc.):

OP STRUCTURE

Is a cut-bank present? _____ *(Y or if N type ctrl-n cb)* Where? _____ *(LB or RB)* Mid-bank distance: **Y**

Cut bank extent: **20** feet **8** *(US, UB, DS)* to **45** feet **UB** *(US, UB, DS)*

Bank damage: **40** *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

Cut bank comments (eg. additional cut banks, protection condition, etc.):

DS
0
30
435

Is channel scour present? **-** *(Y or if N type ctrl-n cs)* Mid-scour distance: _______

Scour dimensions: Length ______ Width ______ Depth: **Y** Positioned **RB** %LB to **90** %RB

Scour comments (eg. additional scour areas, local scouring process, etc.):

67
DS
125
DS

Are there major confluences? **1** *(Y or if N type ctrl-n mc)* How many? **-**

Confluence 1: Distance _____ Enters on _____ *(LB or RB)* Type _____ *(**1**- perennial; **2**- ephemeral)*

Confluence 2: Distance **N** Enters on **-** *(LB or RB)* Type **-** *(**1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

-
-

F. Geomorphic Channel Assessment

107. Stage of reach evolution **-**

1- *Constructed*
2- *Stable*
3- *Aggraded*
4- *Degraded*
5- *Laterally unstable*
6- *Vertically and laterally unstable*

108. Evolution comments *(Channel evolution not considering bridge effects; See HEC-20, Figure 1 for geomorphic descriptors)*:

-

NO CHANNEL SCOUR

Local scour behind/ beside large boulders.

N

-

-

-

-

-

-

-

109. G. Plan View Sketch

- N

point bar (pb)	debris	flow (Q)	stone wall
cut-bank (cb)	rip rap or stone fill	cross-section	other wall
scour hole		ambient channel	

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: ANDOVT00110037 Town: Andover
Road Number: VT 11 County: Windsor
Stream: Middle Branch Williams River

Initials EMB Date: 5/18/98 Checked: MAI

Analysis of contraction scour, live-bed or clear water?

Critical Velocity of Bed Material (converted to English units)
Vc=11.21*y1^0.1667*D50^0.33 with Ss=2.65
(Richardson and Davis, 1995, p. 28, eq. 16)

Approach Section Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	1850	2720	1890
Main Channel Area, ft2	329	348	336
Left overbank area, ft2	113	173	132
Right overbank area, ft2	5	18	9
Top width main channel, ft	41	41	41
Top width L overbank, ft	130	132	131
Top width R overbank, ft	20	36	25
D50 of channel, ft	0.1601	0.1601	0.1601
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	8.0	8.5	8.2
y1, average depth, LOB, ft	0.9	1.3	1.0
y1, average depth, ROB, ft	0.3	0.5	0.4
Total conveyance, approach	29476	34820	31101
Conveyance, main channel	27060	29697	27909
Conveyance, LOB	2340	4739	3048
Conveyance, ROB	76	384	145
Percent discrepancy, conveyance	0.0000	0.0000	-0.0032
Qm, discharge, MC, cfs	1698.4	2319.8	1696.0
Ql, discharge, LOB, cfs	146.9	370.2	185.2
Qr, discharge, ROB, cfs	4.8	30.0	8.8
Vm, mean velocity MC, ft/s	5.2	6.7	5.0
Vl, mean velocity, LOB, ft/s	1.3	2.1	1.4
Vr, mean velocity, ROB, ft/s	1.0	1.7	1.0
Vc-m, crit. velocity, MC, ft/s	8.6	8.7	8.6
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?			
Main Channel	0	0	0

Armoring
Dc=[(1.94*V^2)/(5.75*log(12.27*y/D90))^2]/[0.03*(165-62.4)]
Depth to Armoring=3*(1/Pc-1)

(Federal Highway Administration, 1993)

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	1850	2449	1890
Main channel area (DS), ft2	157	187	160
Main channel width (normal), ft	24.9	24.9	24.9
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	24.9	24.9	24.9
D90, ft	0.4924	0.4924	0.4924
D95, ft	0.7244	0.7244	0.7244
Dc, critical grain size, ft	0.5488	0.6333	0.5474
Pc, Decimal percent coarser than Dc	0.084	0.066	0.085
Depth to armoring, ft	17.95	26.89	17.68

Clear Water Contraction Scour in MAIN CHANNEL

y2 = (Q2^2/(131*Dm^(2/3)*W2^2))^(3/7)   Converted to English Units
ys=y2-y_bridge
(Richardson and Davis, 1995, p. 32, eq. 20, 20a)

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	1850	2720	1890
(Q) discharge thru bridge, cfs	1850	2449	1890
Main channel conveyance	10416	10416	10416
Total conveyance	10416	10416	10416
Q2, bridge MC discharge,cfs	1850	2449	1890
Main channel area, ft2	187	187	187
Main channel width (normal), ft	24.9	24.9	24.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	24.9	24.9	24.9
y_bridge (avg. depth at br.), ft	7.51	7.51	7.51
Dm, median (1.25*D50), ft	0.200125	0.200125	0.200125
y2, depth in contraction,ft	7.87	10.01	8.01
ys, scour depth (y2-ybridge), ft	0.36	2.50	0.51

Pressure Flow Scour (contraction scour for orifice flow conditions)

Chang pressure flow equation   Hb+Ys=Cq*qbr/Vc
Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)   Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79 (<=1)
Umbrell pressure flow equation
(Hb+Ys)/ya=1.1021*[(1-w/ya)*(Va/Vc)]^0.6031
(Richardson and Davis, 1995, p. 144-146)

	Q100	Q500	OtherQ
Q, total, cfs	1850	2720	1890
Q, thru bridge MC, cfs	1850	2449	1890
Vc, critical velocity, ft/s	8.61	8.69	8.64
Va, velocity MC approach, ft/s	5.16	6.67	5.05
Main channel width (normal), ft	24.9	24.9	24.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	24.9	24.9	24.9
qbr, unit discharge, ft2/s	74.3	98.4	75.9
Area of full opening, ft2	186.9	186.9	186.9
Hb, depth of full opening, ft	7.51	7.51	7.51
Fr, Froude number, bridge MC	0.63	1	0.63
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
**Area at downstream face, ft2	157	N/A	160
**Hb, depth at downstream face, ft	6.31	ERR	6.43
**Fr, Froude number at DS face	0.83	ERR	0.82
**Cf, for downstream face (<=1.0)	1.00	N/A	1.00
Elevation of Low Steel, ft	476.24	476.24	476.24
Elevation of Bed, ft	468.73	468.73	468.73
Elevation of Approach, ft	480.16	480.62	480.31
Friction loss, approach, ft	0.16	0.28	0.16
Elevation of WS immediately US, ft	480.00	480.34	480.15
ya, depth immediately US, ft	11.27	11.61	11.42
Mean elevation of deck, ft	480.17	480.17	480.17
w, depth of overflow, ft (>=0)	0.00	0.17	0.00
Cc, vert contrac correction (<=1.0)	0.89	0.89	0.89
**Cc, for downstream face (<=1.0)	0.79	ERR	0.806932
Ys, scour w/Chang equation, ft	**2.15**	**5.23**	**2.38**
Ys, scour w/Umbrell equation, ft	1.61	3.30	1.59

**=for UNsubmerged orifice flow using estimated downstream bridge face properties.

**Ys, scour w/Chang equation, ft	4.61	N/A	4.46
**Ys, scour w/Umbrell equation, ft	2.81	N/A	2.67

In UNsubmerged orifice flow, an adjusted scour depth using the Laursen equation results and the estimated downstream bridge face properties can also be computed (ys=y2-ybridgeDS)

y2, from Laursen's equation, ft	7.87	10.01	8.01
WSEL at downstream face, ft	475.05	--	475.15
Depth at downstream face, ft	6.31	N/A	6.43
Ys, depth of scour (Laursen), ft	1.56	N/A	1.59

Abutment Scour

Froehlich's Abutment Scour
Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1
(Richardson and Davis, 1995, p. 48, eq. 28)

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	1850	2720	1890	1850	2720	1890
a', abut.length blocking flow, ft	142.6	144.4	143.2	23.4	39.9	28.8
Ae, area of blocked flow ft2	216.5	222.4	237.5	46.2	63.5	51.9
Qe, discharge blocked abut.,cfs	654.6	--	690.6	64.8	110.3	70.5
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.02	3.75	2.91	1.40	1.74	1.36
ya, depth of f/p flow, ft	1.52	1.54	1.66	1.97	1.59	1.80
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	30	30	30	150	150	150
K2	0.87	0.87	0.87	1.07	1.07	1.07
Fr, froude number f/p flow	0.432	0.473	0.398	0.176	0.243	0.178
ys, scour depth, ft	**11.88**	**12.63**	**12.03**	**5.91**	**6.92**	**5.93**

HIRE equation (a'/ya > 25)
ys = 4*Fr^0.33*y1*K/0.55
(Richardson and Davis, 1995, p. 49, eq. 29)

a'(abut length blocked, ft)	142.6	144.4	143.2	23.4	39.9	28.8
y1 (depth f/p flow, ft)	1.52	1.54	1.66	1.97	1.59	1.80
a'/y1	93.92	93.76	86.34	11.85	25.07	15.98
Skew correction (p. 49, fig. 16)	1.13	1.13	1.13	0.57	0.57	0.57
Froude no. f/p flow	0.43	0.47	0.40	0.18	0.24	0.18
Ys w/ corr. factor K1/0.55:						
vertical	9.46	9.89	10.06	ERR	4.13	ERR
vertical w/ ww's	7.76	8.11	8.25	ERR	3.39	ERR
spill-through	5.20	5.44	5.53	ERR	2.27	ERR

Abutment riprap Sizing

Isbash Relationship
D50=y*K*Fr^2/(Ss-1) and D50=y*K*(Fr^2)^0.14/(Ss-1)
(Richardson and Davis, 1995, p112, eq. 81,82)

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.83	0.63	0.82	0.83	0.63	0.82
y, depth of flow in bridge, ft	6.31	7.51	6.43	6.31	7.51	6.43
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	1.84	ERR	ERR	1.84	ERR
Fr>0.8 (vertical abut.)	2.50	ERR	2.54	2.50	ERR	2.54